FRACTURE MECHANICS METHOD OF EVALUATING FAILURES IN PELLET-CLADDING INTERACTION ANALYSIS

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SUMMARY

In the application of linear fracture mechanics method for predicting the strength, life and crack propogation rates in the cladding wall of a fuel-rod, knowledge of stress-intensification factors, determined as a function of applied loads and component geometry becomes absolutely necessary. The mechanical behavior of a typical fuel-rod is significantly influenced by the extent of fuel pellet/cladding crack growth and crack healing due to variable power requirements. With high concentrations of local stress levels associated with pellet/cladding interaction at the reactor operating temperatures, the structural integrity of zircaloy cladding can be obtained by a simple fracture mechanics technique. The method of analysis discussed herein essentially develops an efficient finite element computational technique (using thin shell isoparametric elements for cladding and 3-D, 16-node thick shell elements for pellet) to evaluate stress intensity factors for different modes of failure. The method also considers mechanical interaction between the cladding and fuel-pellets at the gapped interface under both thermal and mechanical loads allowing for the crack front in the cladding to vary arbitrarily along the curved wall.

To accommodate combined mechanical and thermal deformations in the outer regions of the fuel-pellets, radial cracks form within the pellets first and subsequently zircaloy cladding deforms with an arbitrarily oriented response and an eventual propogation of the crack front. The model assumes linear deformations of the cracked geometrices together with interacting gapped nodal springs, acting simultaneously at the pellet/cladding contacts. This assumption is based on an arbitrary axisymmetric thermal field. A new model is considered from nonaxisymmetric loads such as mechanical or LOCA conditions. The effects of number of cracks, initial crack widths and interacting springs at the pellet/cladding interface are developed, modelled and analysed for stress concentration factors and crack growth rates. The criteria sought herein are aimed at developing ultimate failure analyses within the fuel-rod, due to mechanical or isothermal fields acting across the entire fuel-assembly of the power ractor.

The present investigation, based on the fracture mechanics technique is also aimed at computing significant parameters such as the influence of magnitude of residual stresses within the fuel-pellets, with changes in the pellet/clad gaps and temperature distribution. Also evaluated is the influence of displacements on temperature distribution and different crack pattern orientations in the pellets. The results have shown that the stress-concentration factors are much higher using compatible pellet/cladding interaction fracture mechanics model, than with non-interacting pellet/cladding models. The stress concentration factors at the inner cladding surface are also determined to be much higher than on the outer wall. Since the pellets restrain the mechanical forces on the cladding wall, the largest radial stresses occur on the inside radius to the crack tips of the pellets with these tips moving steadily outwards. It is also shown that propogating crack growth rates are a function of wall thicknesses. The solutions to number of typical fuel-assembly problems are presented.